CHAPTER 10

RESISTANCE (PART 2)

In addition to the type of material, the length and the cross-sectional area affecting the resistance of a material, temperature change may also affect the final resistance. If a temperature rise produces an increase in the resistance of a material, the material is said to have a positive temperature coefficient of resistance. Materials which react in this way are mainly metals such as copper, silver and aluminium. If a temperature rise produces a decrease in resistance of a material, the material is said to have a negative temperature coefficient of resistance. Materials in this category are carbon, insulators and electrolytes. Some alloys, such as manganin are specially produced to have a zero temperature coefficient of resistance, that is, their resistance in uneffected by temperature change.

10.1 TEMPERATURE COEFFICIENT OF RESISTANCE

The amount of change (increase or decrease) in each ohm of the initial resistance of a material per degree of temperature change, is known as the temperature coefficient of resistance. The following table shows the temperature coefficient of resistance of materials commonly used in the electrical field.

MATERIAL	RESISTIVE TEMPERATURE COEFFICIENT PER °C' at 20°C.
Silver	0.0038
Copper	0.0039
Aluminium	0.0039
Tungsten	0.0045
Nickel	0.006
Manganin	0.000
Constantin	0.000008
Carbon	−0.0005

There are many symbols that are used to signify the temperature coefficient of resistance of a material, one of the most common being the small letter 'a'.

The change in the resistance of a conductor due to the change in the temperature of that conductor is calculated by the following method.

Let -

a = the temperature coefficient of resistance per degree Celsius

t_i = the initial temperature of the material

t_f = the final temperature of the material

t_c = $t_f - t_i$

R_c = the resistance of the material at the initial temperature

R_h = the resistance of the material at the final temperature

Then $a(t_f - t_i)$ will be the resistance change in one ohm of the material after a temperature increase from the initial temperature to the final temperature.

The one ohm of resistance has changed from one to $(1 \pm a(t_f - t_i))$ ohms depending upon whether the material has a positive (+) or negative (−) temperature coefficient of resistance.

If there are R_c ohms of resistance in the material before heat is applied the resistance will increase R_c times that of a one ohm resistor.

The final resistance value after the temperature increase would then be given by —

$$R_h = R_c\,(1 \pm a(t_f - t_i))\ \text{ohms}$$

Example 10.1

The tungsten filament of an incandescent lamp has a resistance of 150 ohms at 20° Celsius. Calculate the resistance of the filament when its temperature has risen to 2000° Celsius.

$a = 0.0045$ per °C

$R_c = 150\ \Omega$

$t_c = (2000 - 20) = 1980$°C

$R_h = ?\ \Omega$

$$R_h = R_c\,(1 + at_c)$$
$$= 150\,(1 + (0.0045 \times 1980))$$
$$= 150\,(1 + 8.91)$$
$$= 150\,(9.91)$$
$$= 1486\ \Omega$$

Example 10.2

A carbon resistor has a resistance of 200 ohms at 20 degrees Celsius. Calculate its resistance if its temperature rose to 80 degrees Celsius.

$a = -0.0005$ per °C

$R_c = 200\ \Omega$

$t_c = (80 - 20) = 60$°C

$R_h = ?\ \Omega$

$$R_h = R_c\,(1 \quad at_c)$$
$$= 200\,(1 + (-0.0005 \times 60))$$
$$= 200\,(1 - 0.03)$$
$$= 200\,(0.97)$$
$$= 194\ \Omega$$

Example 10.3

The resistance of a tungsten wire resistor was found to be 500 ohms after its temperature had been raised 250° Celsius. Calculate the initial resistance of the resistor.

$R_h = 500\ \Omega$

$a = 0.0045$ per °C

$t_c = 250°$ C

$R_c = ?\ \Omega$

$$R_h = R_c\,(1 + a\,t\,c)$$
$$R_c = \frac{R_h}{1 + at_c}$$
$$= \frac{500}{1 + (0.0045 \times 250)}$$
$$= \frac{500}{1 + 1.125}$$
$$= \frac{500}{2.125}$$
$$= 236\ \Omega$$

10.2 EFFECT OF RESISTANCE VARIATIONS DUE TO HEAT

Changes in resistance resulting from changes in temperature due to the passage of electric current invariable causes changes in the magnitude of the current itself. These variations of current can cause damage to equipment or alternatively can be utilised to perform a particular useful operation or function. Some electric globes, for instance, have a very low resistance when cold but a high resistance when at operating temperature. If a globe is switched on to a supply a high current (called inrush current) is drawn by the globe. This current decreases to its correct value as the resistance of the globe filament increases. By inserting a material with a negative temperature coefficient of resistance in series with the globe the inrush current can be regulated so that it does not reach an unsafe value. The current in the circuit causes the negative coefficient material to decrease in resistance while simultaneously increasing the resistance of the positive coefficient material. (Figure 10.1).

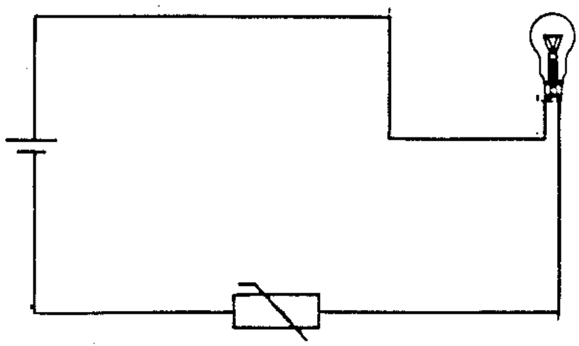

Figure 10.1

Thus the current remains at a fairly constant value. In commercial applications the materials in table 10.1 have been replaced by different metal oxides because the response to temperature change by the metal oxides is more accurate. The oxides are formed into various shapes for different applications and are referred to as thermistors. A typical thermistor is shown in figure 10.2.

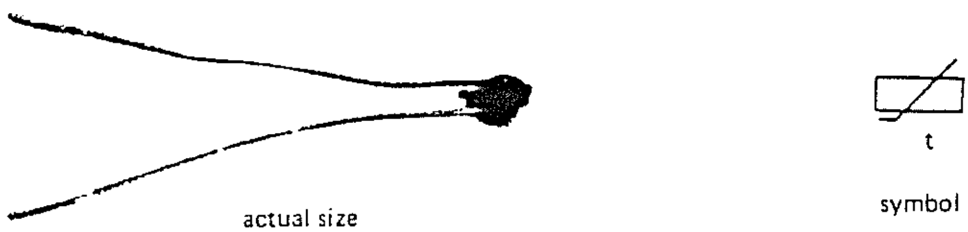

Figure 10.2

Thermistors, in conjunction with a suitable meter, may be used to indicate temperature. The most common instance of this is petrol or deisel engines. The thermistor is located in the block of the engine and connected in series to a temperature indicating meter or red light on the dash board or control panel. (Figure 10.3).

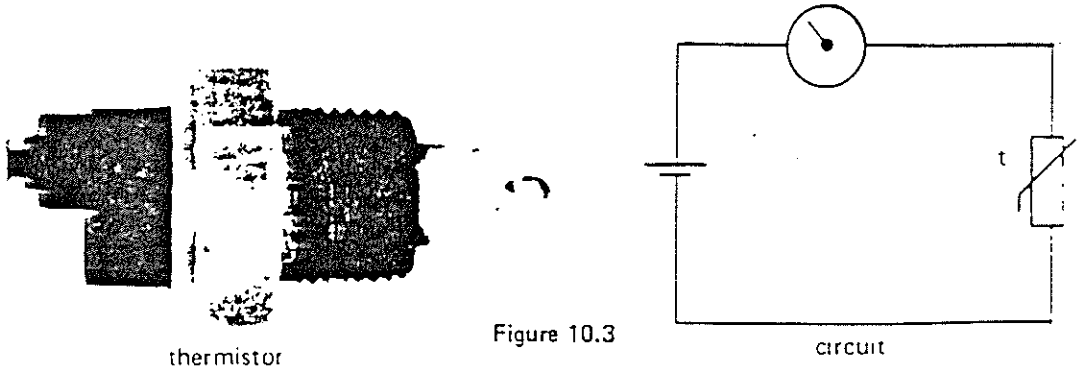

Figure 10.3

As the temperature of the thermistor increases its resistance decreases allowing more current to flow in the circuit. In the case of the indicating meter, which is a milliammeter recalibrated to read temperature, the extra current causes the meter needle to move upscale, while the red light will glow when the current increases sufficiently to generate enough heat to cause illumination. There are many other uses of thermistors, among them being motor protection and heating control circuits.

Equations in this chapter

(1) $$R_h = R_c \left(1 \pm a(t_f - t_i)\right)$$

(2) $$R_h = R_c \left(1 + at_c\right)$$

TUTORIALS 1.10

(1) A tungsten element has a resistance of 250 ohms at 20 degrees celsius. Calculate its resistance when its temperature is 1000 degrees celsius.

(2) The resistance of a copper conductor is 2 ohms at 20 degrees celsius. This resistance increases to 2.1 ohms when the temperature of the conductor is increased. Calculate the final temperature of the conductor.

(3) A carbon resistor at a temperature of 20 degrees celsius has a resistance of 1 megohm. Calculate its resistance at a temperature of 40 degrees celsius.

(4) To what temperature must a coil of copper wire be raised to increase its resistance of 5 ohms at 20 degrees celsius to 7.5 ohms.

(5) The resistance of a coil of copper wire was found to be 52.5 ohms at 15 degrees celsius. After current had been passing through the coil for a certain time its resistance was measured at 57.5 ohms. Calculate the temperature of the coil at this resistance.